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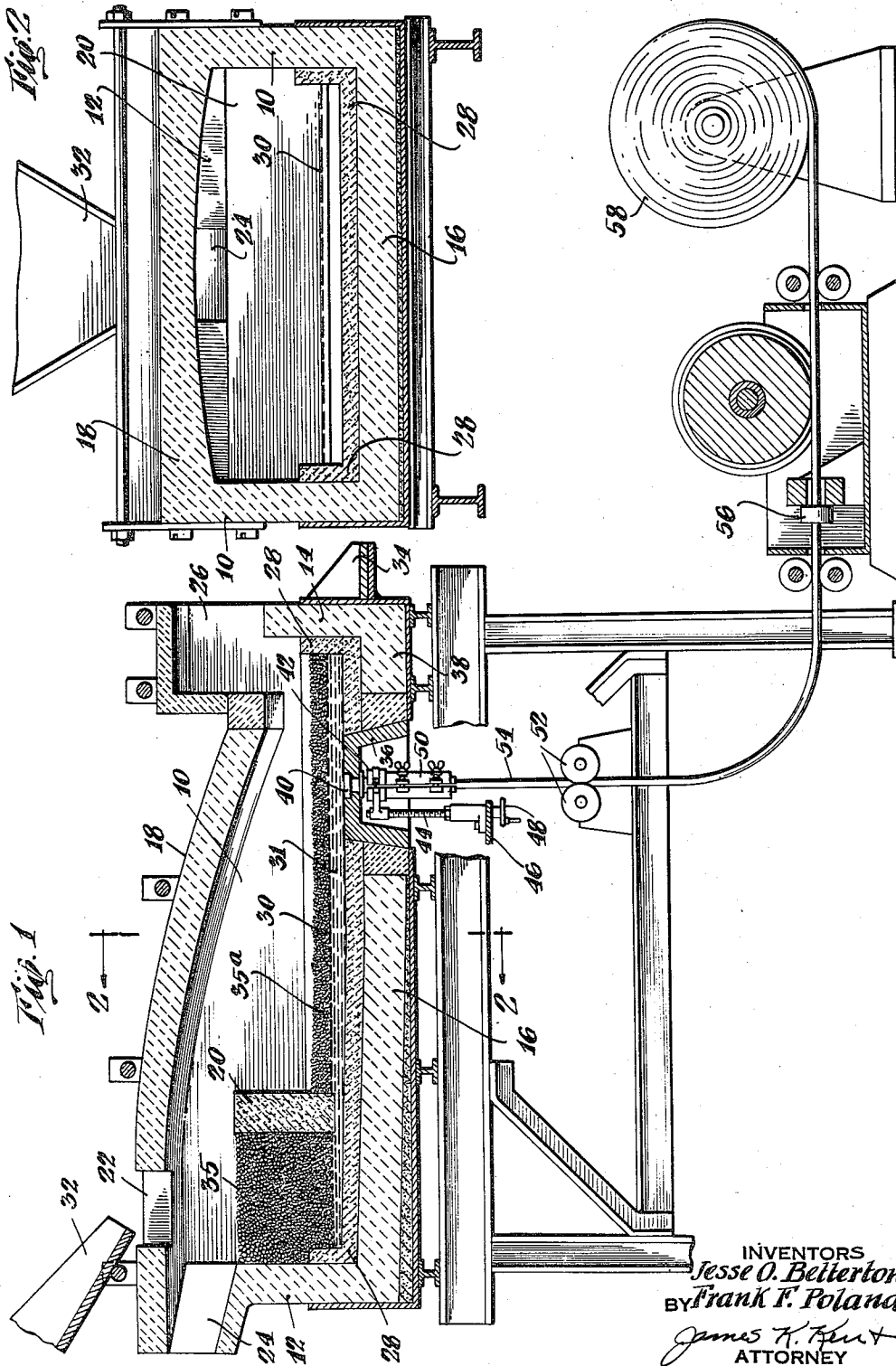
J. O. BETTERTON ET AL

2,264,288

APPARATUS FOR CONTINUOUSLY CASTING METALS

Filed April 13, 1939

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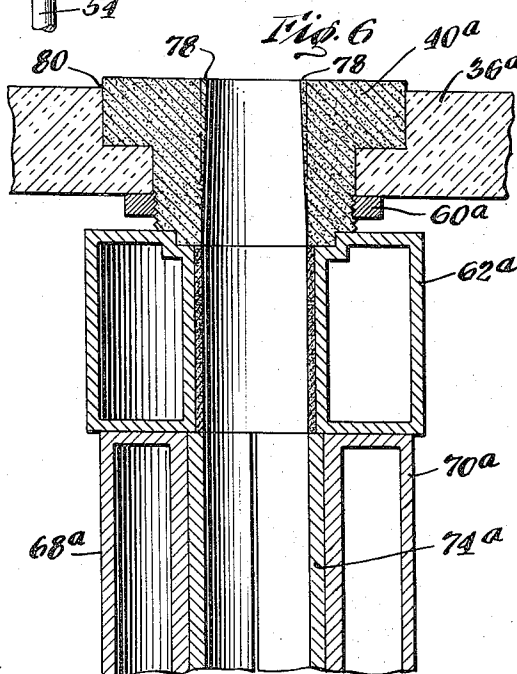
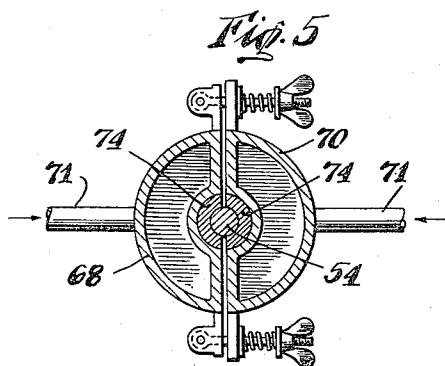
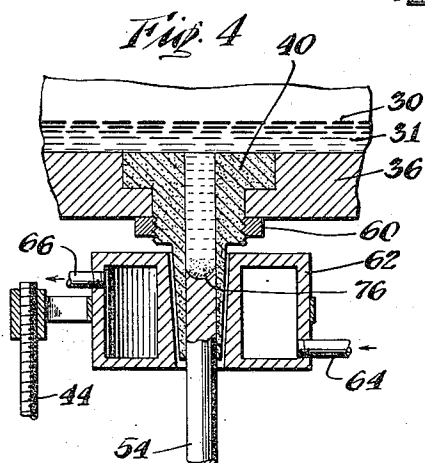
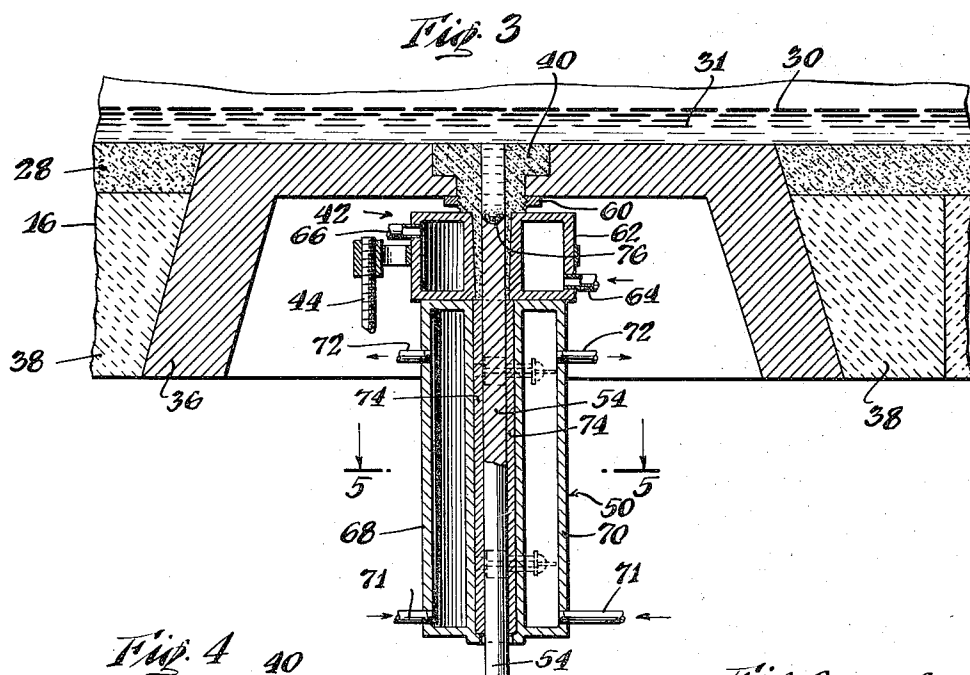
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APPARATUS FOR CONTINUOUSLY CASTING METALS

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6 Sheets-Sheet 2



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APPARATUS FOR CONTINUOUSLY CASTING METALS

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Fig. 7

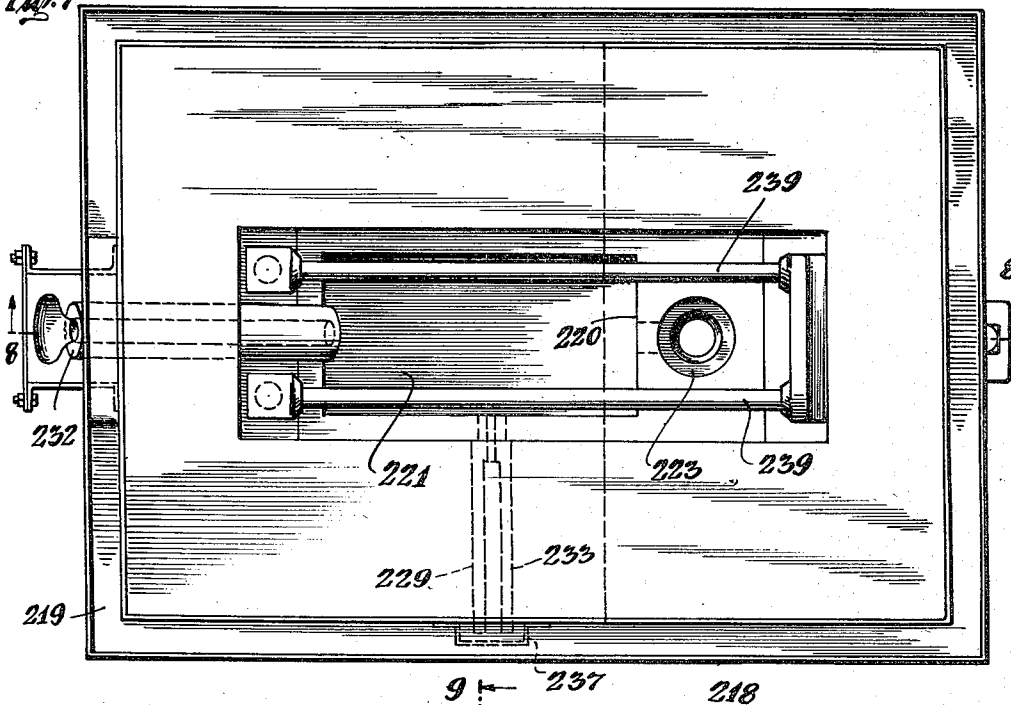
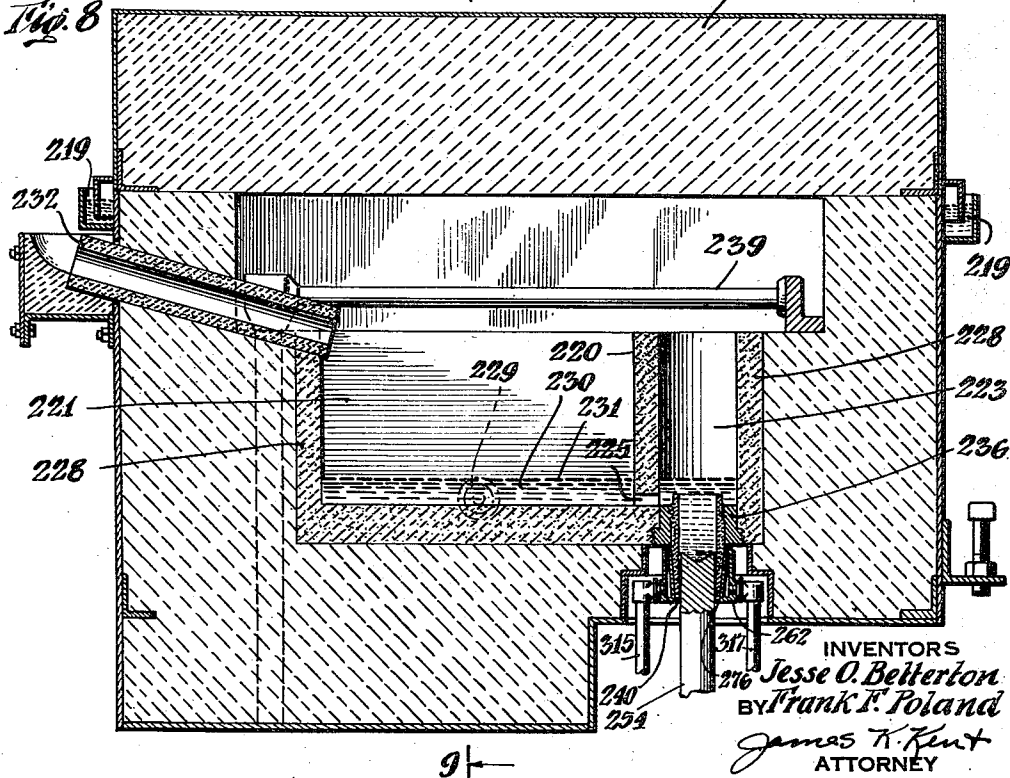


Fig. 8



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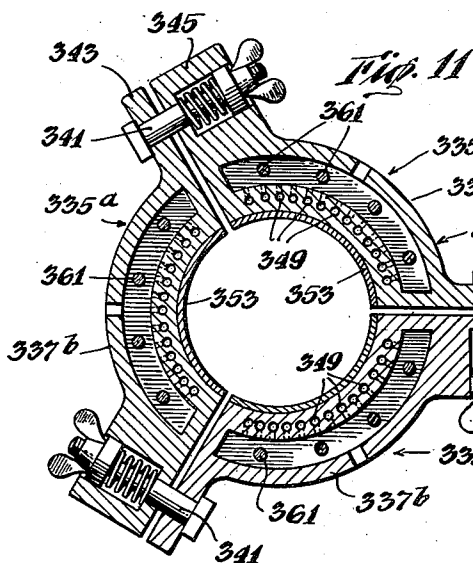
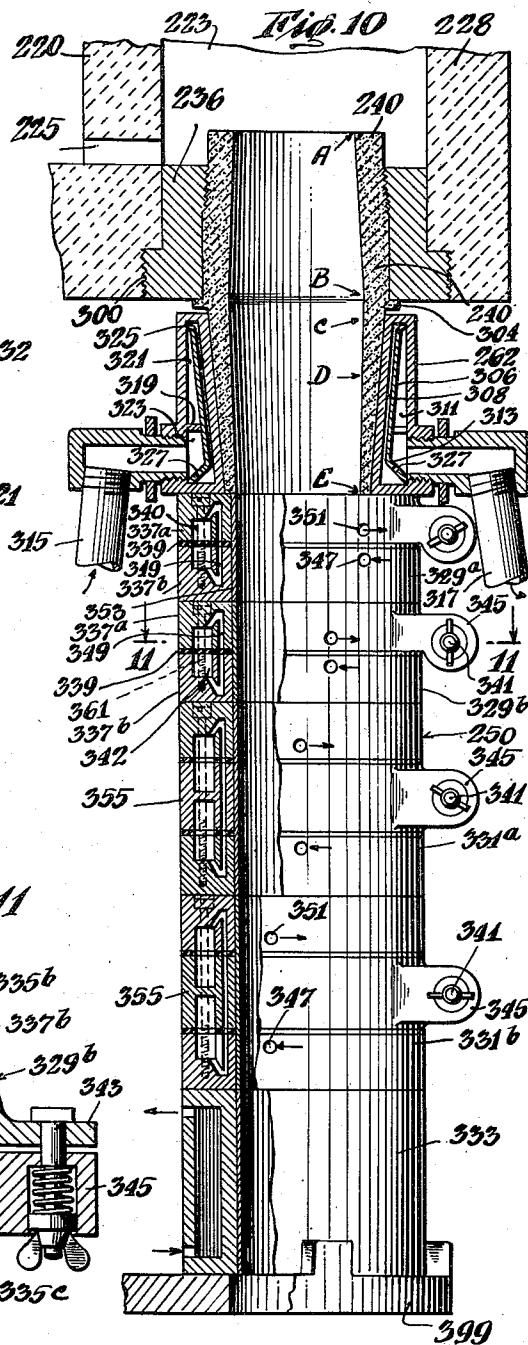
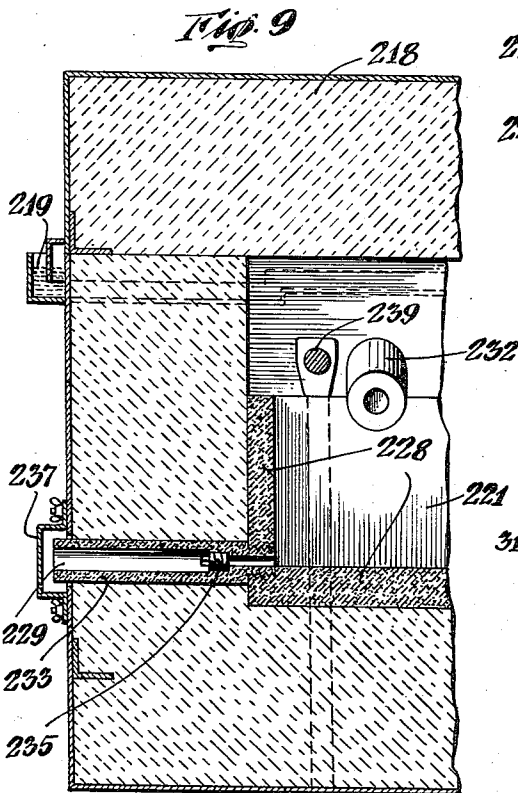
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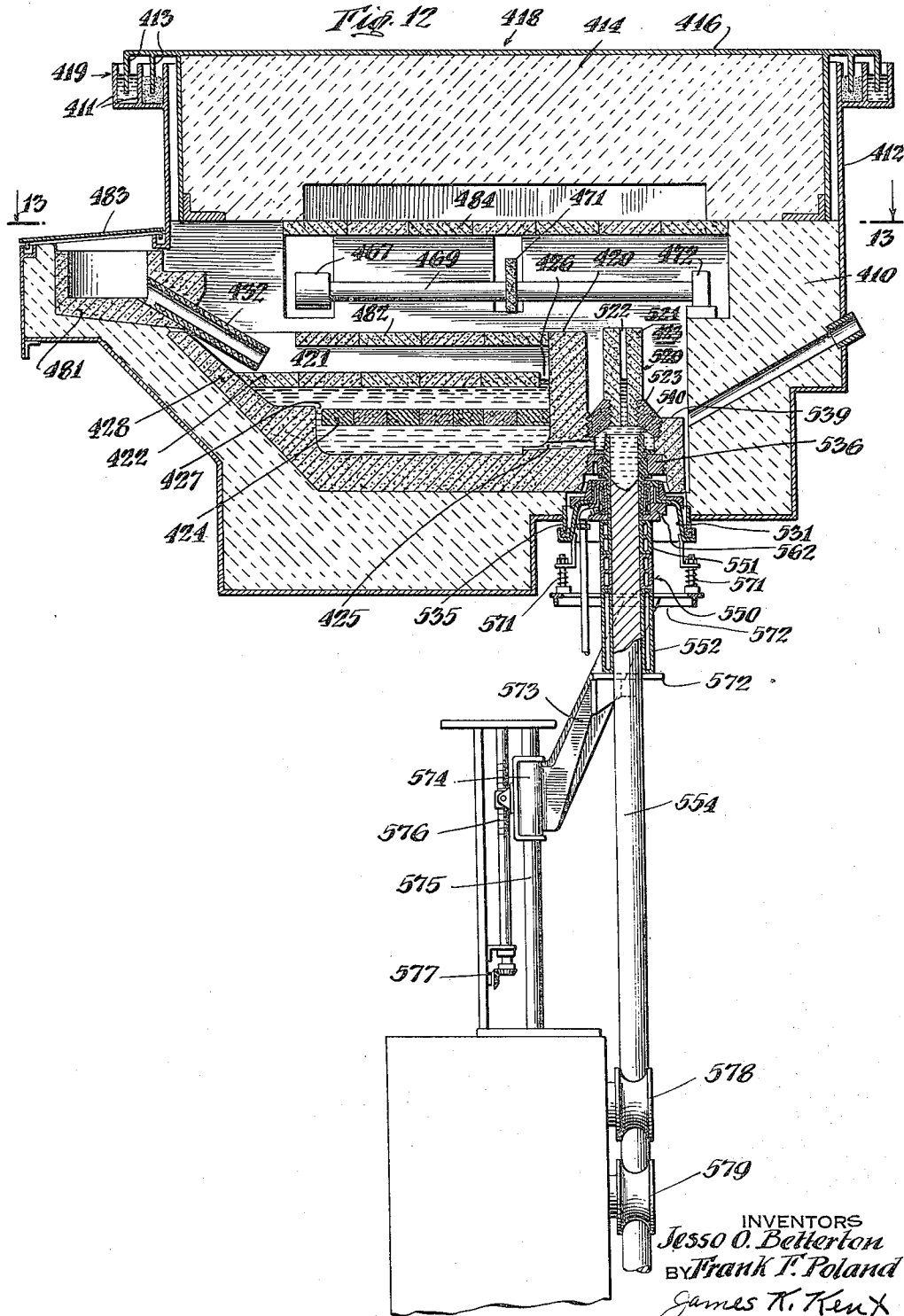
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APPARATUS FOR CONTINUOUSLY CASTING METALS

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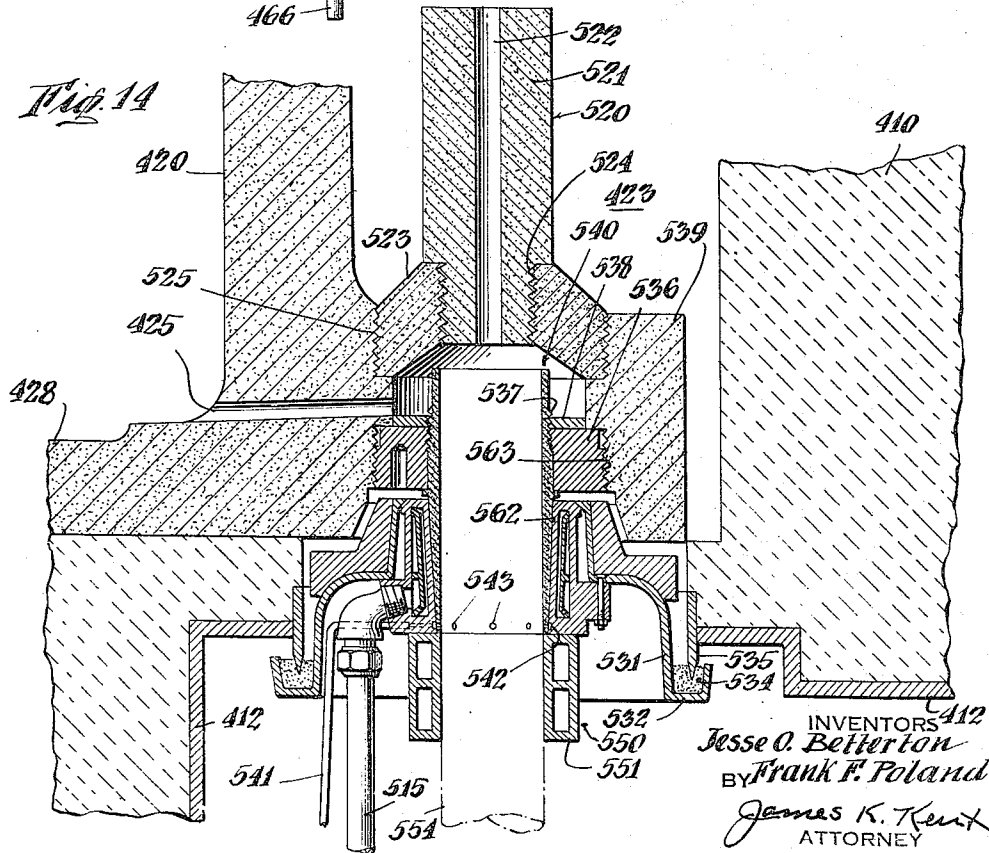
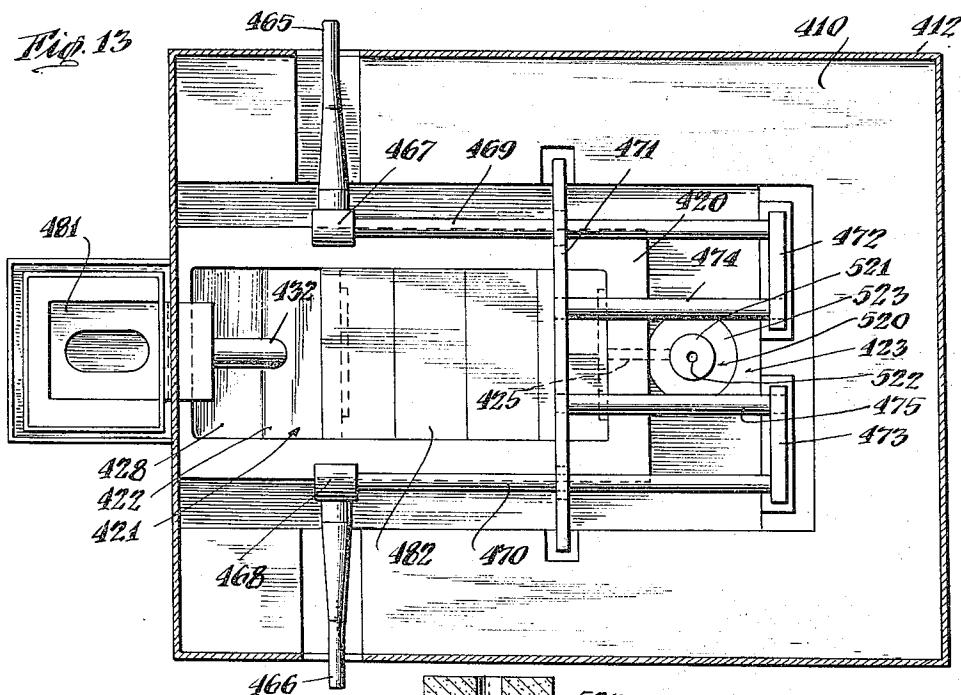
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APPARATUS FOR CONTINUOUSLY CASTING METALS

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UNITED STATES PATENT OFFICE

2,264,288

APPARATUS FOR CONTINUOUSLY CASTING METALS

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Application April 13, 1939, Serial No. 267,688

32 Claims. (Cl. 22—57.2)

This invention relates to apparatus for continuously casting metals.

It has long since been proposed to continuously introduce molten metal into one end of a mold, solidify it therein, and continuously withdraw the solidified metal from the other end of the mold. Such operation is generally referred to as continuous casting and it is an object of the invention to provide improved apparatus for its fulfillment.

While the invention will be described with particular reference to the continuous casting of copper and copper alloys, it will be understood that its principles may be applied to the casting of both ferrous and nonferrous metals and alloys within the scope of the appended claims.

The present application is a continuation-in-part of the application of Jesse O. Betterton and Frank F. Poland, Serial No. 86,600 filed June 22, 1936, for Continuous casting and which has since issued as Patent No. 2,195,809, dated April 2, 1940.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, and the manner in which it may be carried out, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Fig. 1 is a longitudinal section through a casting furnace and related assembly embodying certain principles of the invention,

Fig. 2 is a section taken on the line 2—2 of Fig. 1,

Fig. 3 is an enlarged sectional elevation of the mold or die shown in Fig. 1 and showing details of its mounting in the casting furnace and also details of its cooling facilities,

Fig. 4 is a view similar to that of Fig. 3 but showing the cooling jacket for the mold in a lower position,

Fig. 5 is a sectional plan view taken on line 5—5 of Fig. 3,

Fig. 6 is a sectional elevation of a mold similar to that shown in Fig. 3 but showing the taper of the mold when cold,

Fig. 7 is a plan view of a different form of casting furnace from that shown in Figs. 1 and 2 but embodying certain common and similar principles,

Fig. 8 is a sectional elevation taken on the line 8—8 of Fig. 7,

Fig. 9 is a partial sectional elevation taken on

the line 9—9 of Fig. 8 showing details of a tap hole of the furnace,

Fig. 10 is an enlarged side elevation, partly in section, of a portion of the furnace shown in Fig. 8 showing details of the mold and water jacket constructions, and

Fig. 11 is a sectional plan view taken on the line 11—11 of Fig. 10,

Fig. 12 is a sectional elevation of a further different form of casting furnace and related assembly embodying certain common or similar principles of the invention,

Fig. 13 is a section taken on the line 13—13 of Fig. 12,

Fig. 14 is an enlarged sectional elevation showing details of construction of the mold shown in Fig. 12.

Like reference characters denote like parts in the several figures of the drawings.

Referring to the drawings, there is shown in Figs. 1 and 2 one form of casting or holding furnace and related assembly comprising side walls 10, end walls 12 and 14, bottom 16, roof 18 and arch 20 extending transversely across the furnace near the charging end thereof. A charging port 22 is positioned in roof 18 while end walls 12 and 14 are provided with burner opening 24 and flue 26, respectively. A carbon lining 28 covers the furnace bottom 16 and extends upwardly therefrom along the side walls 10 and end walls 12 and 14 to a point somewhat above the metal line 30 of the furnace. Above port 22 is a charging spout or ladle 32 while at the other end of the furnace is a discharge spout 34 by which the furnace may be drained through a normally closed tap hole (not shown). Beds of carbon 35 and 35a are shown overlying the metal 31 in the furnace.

The bottom 16 and carbon lining 28 are interrupted at the end of the furnace opposite the charging end and on the other side of the arch or baffle 20 to receive an inverted cup-shaped holder 36 which is appropriately secured in place by bricks 38 and refractory cement, said holder serving as the mounting for mold 40 in which the metal is solidified. Surrounding the mold 40 is a cooling jacket 42, said jacket being adjustable with respect to the mold in a readily apparent manner by variable screws 44 carried by bracket 46 and controlled by wheel 48. Below the mold 40 is a mold extension or auxiliary cooling jacket 50. Adjustable grooved rolls 52 for withdrawing the metal casting 54 are shown as are also a die 56 and reel 58 for reducing the size of the casting and coiling it.

The mold 40, which is preferably of dense graphite or other material meeting the specifications set forth in U. S. Letters Patent No. 2,136,394 granted November 15, 1938, to Frank F. Poland and Karl A. Lindner, is countersunk in the holder 36 and secured therein by lock nut 60 as will be apparent from Figs. 3 and 4. The lower end of mold 40 is externally tapered toward its exit and is completely surrounded by a cooling jacket 62 of a metal with high heat conductivity such as forged copper. Said jacket is provided with inlet 64 and outlet 66 for circulation of cooling fluid therethrough and is internally and inversely tapered to complement the external taper of the mold and thus permit longitudinal movement of the jacket with respect to the mold.

As will be seen from Figs. 3 and 5, the mold extension or auxiliary cooling jacket 50 comprises two sections 68, 70 and is positioned below the mold 40 and its cooling jacket 62 where it is supported by any suitable means (not shown). The sections are yieldably joined by a conventional bolt and spring arrangement and each section has a cooling fluid inlet 71 and an outlet 72. The sections are provided with liners 74 which are of ordinary graphite or the like and which contact the cast rod 54.

In Figs. 3 and 4, the mold 40 is illustrated as filled with molten metal undergoing solidification to form the cast rod 54, the intermediate zone, that is, the zone between the fully molten metal and the fully solidified metal, being indicated by reference character 76. It will be noted that in these figures, the mold 40 presents a straight bore.

Fig. 6 shows a mold and assembly that is similar to that shown in Figs. 3 and 4 (similar parts being indicated by reference characters carrying the suffix *a*) but illustrating the mold at room temperature, at which temperature the mold exhibits a bore internally tapered toward its inlet as indicated by reference character 78. A taper of 0.25 inch per foot has been found satisfactory for casting copper rods in the neighborhood of an inch in diameter, the bore of the mold apparently becoming practically straight at casting temperatures as illustrated in Figs. 3 and 4. Also, in Fig. 6 the top surface of the mold 40*a* projects slightly above the holder 36*a* as indicated at 80 and the contacting surfaces of the water jacket 62*a* and mold are non-tapered, the former being shrunk tightly around the latter.

Referring to the modified form of furnace and mold assembly illustrated in Figs. 7-11, the furnace is shown with a removable roof or cover 218 and sealing means 219 formed by co-operating flanged members affixed to the respective perimeters of the cover and side walls and end walls of the furnace as clearly indicated in Figs. 7, 8 and 9. The interior of the furnace is provided with a carbon lining 228 which is preferably of commercially pure graphite of low ash content (2.5% or less) and an arch or baffle 220, likewise of graphite, divides the furnace into two compartments: a metal receiving compartment 221 and a mold compartment 223, with a passageway 225 therebetween. A metal charging conduit 232 of graphite is provided for compartment 221 as is also a tap hole 229 comprising a graphite conduit 233 internally threaded to receive screw plug 235, the exteriorly projecting portion of the tap hole being normally enclosed by cover

237 (Fig. 9). Graphite resistors 239 are provided for heating the furnace electrically. The metal line 231 of the metal 230 is indicated in Fig. 8 as is also the intermediate zone 276 in the mold 240.

In Fig. 10 there is shown not only the details of the mold 240 and its cooling jacket 262 which are indicated in Fig. 8 but also the details of the mold extension or auxiliary cooling means 250 omitted in that figure. Referring to Fig. 10 it will be seen that mold 240 is mounted in holder 236 which in turn interrupts the furnace hearth and is secured therein by screw threads 300. Screw threads 302 and the annular collar portion 304 of the mold insure a metal tight mounting of the mold in the holder. The mold 240 is of dense graphite of the specifications previously mentioned with respect to mold 40 and is so proportioned as to project into compartment 223 a short distance above the upper face of holder 236 and the bottom lining of the furnace. It will be seen that the portion of the mold 240 which extends below the holder 236 and is surrounded by the cooling jacket 262 is externally tapered so that the mold wall becomes progressively thinner from the projecting collar 304 to the mold exit.

A feature of the mold 240, which is intended for the production of relatively large diameter castings, resides in its internal contour, same being designed with the object of providing uniform, close contact of the metal with the surface of the mold bore or channel throughout its passage therethrough without, however, any binding or pinching action. Naturally, this internal contour is susceptible to variation with different metals, differences in the diameter of the casting, etc. so that the following specifications, which have proved satisfactory in the commercial production of three-inch copper billets, are to be regarded as illustrative.

In this instance the dense graphite mold 240 had an overall length of eight and one-sixteenth inches with a diameter of 3.155 inches at its intake, indicated at A in Fig. 10. From point A to B, a distance of three and thirteen-sixteenth inches, the diameter uniformly increased to 3.177 inches and from point B the diameter was increased to 3.187 at point C, a distance of one half an inch. During the next inch of length (point C to point D) the diameter was constant and in the remaining two and three quarter inches of its length (point D to point E) the diameter was uniformly decreased to 3.16 inches. The thickness of the mold wall was substantially as follows: approximately 0.4 inch from its intake to threads 302, about 0.485 inch throughout the length from said threads to point C (except for collar 304), and then uniformly decreasing in the last four inches of length from about 0.473 inch to 0.17 inch, such portion providing a uniform tapered fit for the jacket 262.

The cooling jacket 262, which is of forged copper and is internally tapered to fit the external taper of mold 240, has a partition member 306 dividing the interior of the jacket into two chambers 308 and 311, the chamber 308 being of substantially uniform width except at its bottom where the partition 306 flares outwardly to form apron 313. The fluid inlet to the jacket is designated at 315 and the outlet at 317. An annular partition member 319 extends almost completely around member 306 thus dividing chamber 311 into upper and lower

portions, 321 and 323 respectively. Ports 325 are provided at the top of partition 306 and ports 327 are provided in apron 313. Thus, it will be apparent, that water introduced under pressure through inlet 315 will pass through ports 327, upwardly in chamber 308, through ports 325 into chamber 321, thence through the break in partition member 319 into chamber 323 and out through outlet 317 thereby cooling the mold 240 by a thin stream or film of water circulated at high velocity in accordance with the well known and established fact that cooling is a surface, rather than a volume, phenomenon.

Still referring to Fig. 10 (also Fig. 11), the mold extension or auxiliary cooling jacket 250 is illustrated as comprising a plurality of units 329a, 329b, 331a, 331b, and 333. The first two units, 329a and 329b, are identical, each being shown as comprising a plurality of cooperating cast segments, 335a, 335b and 335c with each segment composed of an upper half or section 337a and a lower half or section 337b. The sections are assembled with a plate 339 defining chambers 340 and 342, and are held firmly together by screw bolts 361 while the several segments are yieldably coupled by spring bolts 341 passed through complementary lugs 343 and 345 of adjacent sections.

Each of the segments is provided with a cooling fluid inlet 347 to chamber 342 from whence the cooling fluid passes upwardly through ducts 349 into chamber 340 and thence out through outlet 351. The sections of the various segments are preferably of cast aluminum because of its lightness, high heat conductivity and ease of casting and each has a lining 353 of ordinary electrode graphite which contacts the casting 254 (Fig. 8).

The units 331a and 331b are similar to units 329a and 329b except for an intermediate section 355 in each segment and minor changes incident to its inclusion, all of which will be readily apparent from the drawings. The unit 333 differs from the others in that the segments are not sectioned, the unit being similar in construction to the mold extension 50 shown in Fig. 3. A holder 399 supports the various units of the mold extension 250 in alignment with mold 240, the holder being supported independently of the mold 240 and its jacket 262 in any suitable manner not shown.

Referring to the modified form of apparatus shown in Figs. 12 and 13, the furnace is shown comprising a refractory body 410 housed by steel shell 412 and provided with a removable cover 418. The cover comprises a refractory body 414 enclosed in a steel shell 416 and has a double seal 419 extending around the whole top of the furnace and formed by cooperating flanged members 411 and 413 welded to shells 412 and 416, respectively. Sealing is appropriately effected by filling the compartments formed by flanges 411 with sand or an equivalent granular medium and with a non-volatile liquid such as a high petroleum distillate fraction, respectively.

The laboratory of the furnace is provided with a graphite crucible 428, the one end 420 of which divides the furnace into a metal receiving compartment 421 and a casting compartment 423. A port 425 in wall 420 constitutes the sole path of flow for metal from compartment 421 into mold 540. Above the bottom of crucible 428 and suitably supported by the sides thereof are graphite blocks forming a pair of false bottoms 422 and 424 provided with ports 426 and 427, re-

spectively. A graphite conduit 432 leads from a charging ladle or reservoir 481 provided with sealed cover 483 to the top of false bottom 422.

The furnace is heated electrically by graphite resistor elements horizontally positioned between the floor 482 and ceiling 484, both of which are made of graphite blocks or slabs and supported by channels in furnace side walls. The heating elements are shown best in Fig. 13 and comprise a pair of graphite resistor terminals 465, 466 terminating interiorly of the furnace in terminal connector blocks 467, 468. Graphite resistors 469, 470 pass through holes in the graphite support plate 471 and connect the resistor blocks 467, 468 with graphite contact plates 472, 473, respectively, which plates are connected with the support plate 471 by shorter graphite resistors 474, 475.

Mounted in the mold compartment 423 (Figs. 12 and 14) is the mold 540 which, like molds 40 and 240 heretofore described, is machined from dense graphite meeting the specifications of the aforesaid patent to Poland & Lindner. The mold 540 and the cooling jacket 562 therefore are similar in most respects to the like members in Fig. 10. The mold is shown as secured in a holder 536 by threads 537 which engage the holder and by a graphite washer 538. The holder is in turn mounted in the extension 539 of the graphite crucible 428 and secured by screw threads 563. Cooling fluid for the jacket 262 is supplied by pipe 515 and circulated as previously described with reference to jacket 262 (Fig. 10) and thence similarly discharged through another pipe not shown.

A seal is provided to prevent access of air to the otherwise exposed surface of the extension 539 of the crucible 428, holder 536 and mold 540 by means of a shell 531 provided with a channel 532 filled with sand or other sealing medium 534 and into which extends sealing ring 535 when the mold assembly is in operative position. A pipe 541 is provided for introducing a non-oxidizing gas into the channel 542 at the lower end of the jacket 562 and thence through ports 543 in the end of the mold 540 to prevent oxidation of the new casting.

A further feature of the instant furnace is a gas venting means 520 which is constructed of graphite and positioned directly above the intake of mold 540, said means comprising a stack 521 with vent 522 secured in a graphite base 523 by cooperating threads 524. The base is in turn mounted in wall 420 and extension 539 of crucible 428 by means of threads 525. The vent 522, it will be observed, is of much smaller cross-sectional area than the cavity of mold 540 so that as the metal in the vent seeks the same level as that in the crucible, the hydrostatic pressure of the metal entering the mold to undergo solidification will not be excessive. Accordingly, there is secured the effect of only a low head of metal above that in the mold. Further, the gas venting means assures the direct and ready elimination of the gas as same is expelled by the freezing metal without permitting the released gas to contact the main body of metal in the furnace.

Immediately below the mold is a mold extension or auxiliary cooling means 550 comprising a plurality of shorter sectioned units 551 and a longer sectioned unit 552. The entire mold assembly is resiliently mounted through springs 571 on a support 572 which is carried by an arm 573 of a bracket 574. The bracket 574 is

adjustable up and down on the standard 575 by screw shaft 576 driven by bevel gears 577 by a source of power not shown. Pairs of oppositely disposed, power driven rolls 578, 579 are provided for withdrawing the casting 554 from the mold 540 as solidification is effected.

In conducting the continuous casting process there are various factors which should be appreciated if the operation is to be conducted on a satisfactory commercial basis. For the most part, these factors and the principles underlying them are discussed in detail in applicants' aforesaid copending application Serial No. 86,600 and it will be seen, as the present description proceeds, that the proper observance of these factors is greatly facilitated by the apparatus provided by the instant invention.

Following the preliminary preparation of the copper (or other metal) to be cast, that is, rendering it commercially gas-free and deoxidized, same is delivered to a furnace of the kind illustrated in the drawings for casting.

In the type of furnace shown in Figs. 1 and 2, the copper is charged through the port 22 into the deep bed of carbon 35 (pre-ignited charcoal of low sulphur content), onto the hearth whence it passes under arch 20 into the second compartment of the furnace containing the mold 40. A layer of carbon 35a is provided in this second or mold compartment so that the copper is not contaminated by the combustion gases which are supplied to the furnace through opening 24 from a suitable gas or oil burner (not shown) and pass out through the flue 26. Accordingly, the copper is maintained both in its previously prepared condition and at the correct temperature for entering the mold. Similarly, in the type of furnace shown in Figs. 7-9, the copper is charged through the graphite conduit 232 into the metal-receiving compartment 221 from which it flows into the mold compartment 223 via the passageway 225 in arch 220. Inasmuch, however, as this furnace is electrically heated by resistors 239, the bed of carbon over the molten metal may be omitted as is also true of the furnace illustrated in Figs. 12-14. In this latter furnace the prepared copper charged to ladle 481 passes through conduit 432 onto the false bottom 422 to the other end of the furnace and through port 426 onto the second false bottom 424 where it flows in the reverse direction to port 427 and onto the floor of the crucible 428. Again reversing the direction the copper flows through passageway 425 in wall 420 and into the mold 540.

It will be noted that in all types of furnaces the metal-contacting surfaces are of carbon, as is also true of the molds, so that from the time the molten metal first enters the furnace until the casting is withdrawn from the mold, it is in continuous contact with these surfaces and is maintained in its proper gas-free, deoxidized condition. Further, in all furnaces, the metal is charged at a location remote from the mold and the graphite partition or arch members 20, 220 and 420, respectively, extend below the normal metal line of the furnace. These features, as well as that of extending the mold inlet a short distance above the floor of the furnace (Figs. 8-10 and Figs. 12 and 14) permit replenishment of the charge in the furnace without imparting any substantial turbulence of the metal undergoing solidification in the mold thereby permitting the casting operation to proceed with-

out interruption. The importance of thus being able to replenish the supply of molten metal without disturbing the continuity of the casting operation is further emphasized when it is borne in mind that the head of metal above that undergoing solidification in the mold must not be too high at any time if imperfections in the casting are to be avoided.

It will be understood that prior to charging the furnace, a suitable plug is provided for the mold and mold extension which prevents the molten copper from running out of the mold prior to solidification therein. This plug ordinarily consists of the last part of the casting from a previous run and constitutes the starting rod for withdrawing the casting from the mold. To initiate the actual casting operation, water is circulated through the mold to solidify the copper therein and weld it to the plug or starting rod which is then slowly withdrawn, the speed of withdrawal being gradually increased (with proper attention being paid to the mold cooling rate) until the full commercial casting rate is attained and thereafter continued without jerking of the casting. For this purpose, there are provided flanged guide rolls 52 (Fig. 1) or 578, 579 (Fig. 2), which may be adjustable with respect to each other to accommodate castings of different diameters and between which the casting 54, (or 554) passes. Either roll may be power driven from a variable-speed motor appropriately coupled to a speed reducer, the motor being, at all times, responsive to suitable rheostat control. After passing the rolls 52, the casting may be drawn through a die 56 (or a series of dies) and wound on to a reel 58 as shown in Fig. 1. Such treatment will ordinarily obtain in the case of castings of relatively small diameters; with castings of larger diameters, as for the production of billets and for which the apparatus shown in Figs. 7-14 is well adapted, a sawing mechanism may be substituted for the die and reel to sever the casting at predetermined intervals.

An important consideration in continuously producing sound castings on a commercial scale is that of properly correlating the cooling and casting rates to obtain radial crystallization in the casting, that is, a structure in which the copper crystals are disposed substantially at right angles to the axis of the casting or at the most are inclined from the periphery of the casting toward the axis thereof at an angle of not less than 45 degrees. Such correlation not only produces a superior product but, in addition, guarantees that the intermediate zone in which the molten copper undergoes solidification is sufficiently shallow to avoid accumulation and entrapment of gas that would otherwise result and cause breakage of the casting or, at least, unsoundness therein.

Various techniques may be indulged in to correlate the cooling and casting rates in starting up the casting operation and bringing it to full commercial speed. Thus, with a tapered mold and adjustable water jacket as illustrated in Figs. 3 and 4, the maximum flow of cooling water can be employed at the outset by slightly lowering the jacket (Fig. 4) so that the metal within the mold receives only a part of the full cooling effect of which the jacket is capable. The rod 54 is then slowly withdrawn thereby initiating the casting operation. Thereafter, the speed of withdrawal is gradually increased and at the same time the fit of the jacket 62 on the mold 40 is made tighter by turning the screw 44 thereby increasing the

amount of heat withdrawn from the molten metal so that when the full withdrawal speed is reached the position of the jacket on the mold is as shown in Fig. 3.

On the other hand, with the type of apparatus shown in Fig. 6 in which the jacket 62a is shrunk on the mold 40a, the cooling of the metal in the mold can be controlled during the starting up period by regulating the flow of water through the mold, the gradual, steady increase of the speed of withdrawal of the casting being accompanied by a corresponding increase in the circulation of the water through the jacket. Of course, with the type of mold shown in Figs. 3 and 4, or Figs. 8 and 10, or Figs. 12 and 14, a combination of the procedures outlined can be employed. In any event, however, the rate at which the metal in the mold is cooled and the speed at which the casting is withdrawn should be so correlated as to obtain the radial crystallization hereinbefore mentioned.

In considering the proper correlation of the cooling and withdrawal rates, it is to be noted that in the absence of the influence of other factors, the efficiency of the former will determine the maximum speed of the latter. Accordingly, the apparatus of the invention embodies certain features of construction that enhance the extraction of heat from the metal and thus permit high commercial casting rates to be attained.

Thus, that portion of the mold wall enclosed by the cooling jacket and through which the major part of the heat is extracted in forming the casting is made as thin as is compatible with requisite mechanical strength. In addition, the contacting surfaces of the cooling jacket and mold are accurately machined to insure an even, close fit whether they be tapered (Figs. 3, 4, 10, 14) or straight with the jacket shrunk on the mold (Fig. 6) or both. Further, to obtain the maximum cooling efficiency for the amount of water circulated, which is of particular importance in making castings of large cross-section, the water jacket may appropriately take the improved design shown in Figs. 10 and 14.

A feature which has been found to exert a marked effect upon the rate of heat extraction, as well as upon the success of the process generally, is the internal configuration or longitudinal contour of the mold. While same is, of course, subject to variation with changes in the kind of metal cast, the cross-sectional area of the casting, etc., it has been found generally that the interior of the mold should present, during the casting process, a substantially straight wall from the inlet to the freezing zone and that from the end of that zone to the outlet, there should be a contact continually close but non-binding between the mold wall and the solidified casting.

Thus, in casting copper rods in the neighborhood of an inch in diameter, it has been found that a mold having an internal diverging taper of 0.25 inch per foot from the inlet to the zone of solidification and thence straight to the mold outlet presents a substantially straight bore throughout under casting conditions and is eminently satisfactory. On the other hand, in casting, say, 3-inch copper billets, it has been found that a definite converging taper of the mold wall from the end of the freezing zone to the mold outlet is highly beneficial as the contraction of the casting is accentuated in the case of larger castings and unless it is compensated for in the interior contour of the mold the efficiency of heat extraction is noticeably impaired. A

specific example of a mold provided with such a taper has been previously described.

The following comparative examples of casting one-inch copper rod will serve to illustrate the influence exerted by various of the above factors upon the rate of heat extraction and, hence, upon the casting or withdrawal rate. In the first instance there was employed a mold having a taper of 0.25 inch diverging from inlet to outlet, the mold wall being 0.75 inch thick and the water jacket 3 inches long by 2.5 inches in diameter through which water was circulated at the rate of 10.5 lbs. per minute. Under such conditions a continuous casting rate of 4 inches per minute was the maximum obtainable. In the second instance the bore of the mold was such as to present a straight line resultant under casting and the mold wall was only 0.25 inch thick. The water jacket was 3 inches long by 1.5 inches in diameter and the water circulation was 70 lbs. per minute. Under these conditions a sustained casting speed of 20 inches per minute was easily attained.

Immediately past the exit of the mold proper there is normally provided a mold extension or auxiliary cooling jacket, indicated by reference characters 50, 250 and 550 in Figs. 3, 10 and 12, respectively, which engages the hot casting as it emerges from the mold. As previously described, the mold extension is sectioned or segmented and yieldably assembled so as to be self-accommodating to the particular casting passing therethrough. Among other functions, the mold extension cools the hot casting to a temperature at which it can be readily handled and serves as a safety device in that it insures sufficient cooling to maintain a plug of metal in the die and thus prevent a run-out of molten metal if, for any reason, there should be a break in the casting. Further, the graphite lining, indicated by reference characters 74 and 353 in Figs. 3 and 10, respectively, and the cooling effect of the jacket serve to inhibit oxidation of the hot casting which would result if no mold extension were used.

It will be apparent from the foregoing description, that the present invention provides improved apparatus for conducting the continuous casting process on a truly commercial scale. Naturally, the details of construction and operation herein described in order to fully illustrate the invention may be modified to adapt it to varying conditions and uses within the scope of the invention and without departing from the underlying principles thereof.

What is claimed is:

1. Apparatus for the continuous casting of metal comprising a furnace provided with an interior partition member defining a molten metal receiving compartment and a metal casting compartment, said partition being provided with a passageway between compartments which passageway is beneath the normal metal line of the furnace, a mold in communication with said casting compartment continuously receiving molten metal therefrom into one end of the mold and continuously discharging solidified metal from the other end thereof, said apparatus presenting a continuous surface of carbon to metal passed therethrough.

2. Apparatus for continuously casting metal comprising a furnace divided into a metal receiving compartment and a metal casting compartment, heating means for said furnace, and a mold in communication with said casting com-

partment adapted to continuously receive molten metal from said compartment and solidify same prior to emergence from said mold, said apparatus presenting a continuous carbonaceous facing to metal from the time it enters said furnace until it leaves said mold.

3. Apparatus for continuously casting metal comprising a furnace interiorly divided into first and second compartments, a mold mounted in said second compartment for continuously receiving molten metal from said compartment and continuously discharging solidified metal, and means for introducing metal into said first compartment and thence into said second compartment with a minimum of turbulence to the metal in the mold, all surfaces of said apparatus contacting the metal consisting of graphite.

4. Apparatus for continuously casting metal comprising the combination with a furnace in which all interior metal-contacting surfaces are provided with a carbonaceous lining, of a mold mounted in the hearth of said furnace, said mold having a cavity extending completely therethrough and provided with cooling instrumentalities for continuously solidifying in, and discharging from, the mold, metal continuously introduced from the furnace, and means for supplying metal to be cast from a source thereof into the furnace and thence delivering same to said mold while maintaining the metal in the mold in a quiescent state.

5. Apparatus for continuously casting metal comprising the combination with a furnace in which all interior metal-contacting surfaces are provided with a carbonaceous lining, of a mold mounted in the hearth of said furnace for continuously receiving molten metal from the latter and continuously discharging a casting of indeterminate length, carbon resistors for maintaining metal in said furnace at desired temperature, and means for receiving metal to be cast from a source thereof and delivering same to said mold while maintaining the metal in the mold in a quiescent state.

6. Apparatus for continuously casting metal comprising a furnace with a graphite-lined hearth defining a reservoir for molten metal, carbon resistors adjacent said hearth for controlling the temperature of the molten metal, and a mold communicating with said reservoir for continuously receiving molten metal therefrom and for solidifying it into a casting of indeterminate length.

7. Apparatus for continuously casting metal comprising a furnace with a graphite-lined hearth defining a reservoir for molten metal, a mold communicating with said reservoir for continuously receiving molten metal therefrom and for solidifying it into a casting of indeterminate length, and a graphite drain for said hearth, said drain being internally threaded for receiving an externally threaded graphite plug closure for said drain.

8. Apparatus for continuously casting metal comprising a furnace for receiving molten metal to be cast, a mold mounted vertically in the hearth of said furnace into one end of which molten metal continuously flows and from the other end of which the solidified metal is continuously discharged, the top of said mold rising a short distance above said hearth, a removable cover for said furnace, and sealing means for said cover, said apparatus interiorly presenting a carbonaceous facing to the molten metal throughout its entire passage through said furnace.

9. Apparatus for continuously casting metal comprising a reservoir for molten metal, all metal-contacting surfaces of which are of graphite, a mold holder externally threaded for mounting in the bottom of said reservoir and internally threaded to receive a mold, a mold provided with a cooling jacket for solidifying in, and discharging from, the mold, molten metal continuously introduced from said reservoir, said mold being externally threaded to mesh with said holder, the top of said mold projecting a short distance above the level of the holder and the bottom of the reservoir but below the normal metal line of the latter.

10. Apparatus for the continuous casting of metals comprising a receptacle for holding molten metal in which the metal-contacting surfaces are of commercially pure graphite containing at least 97.5% carbon, a mold for continuously receiving molten metal from said receptacle having an internal passage presenting a continuous graphite surface to metal passed therethrough, cooling instrumentalities of high heat conductivity for said mold to effect rapid solidification of metal in its continuous passage therethrough, and means substantially preventing turbulence incident to replenishment of metal in the receptacle from being transmitted to the metal in the mold passage.

11. Apparatus for the continuous casting of metals comprising a container for molten metal to be cast, a vertically-disposed mold with a cavity extending completely therethrough and having its inlet in direct communication with the interior of said container, and a cooling jacket for the mold, the mold wall defining the mold cavity having a compound configuration adapted to maintain the metal in intimate contact with the cavity wall throughout the entire passage of the metal through the mold.

12. Apparatus for the continuous casting of metal comprising a graphite-lined furnace chamber defining a reservoir for molten metal, a mold with a passage therethrough into one end of which metal continuously flows from said reservoir and from the other end of which solidified metal is continuously withdrawn, and cooling means for extracting heat from the metal in said passage via the mold wall, the mold wall defining said passage being of graphite and having a compound configuration adapted to maintain a uniform wiping contact with the metal as it moves through said passage.

13. Apparatus for the continuous casting of metal comprising a reservoir for molten metal to be cast, a mold with a passage therethrough into one end of which metal continuously flows from said reservoir and from the other end of which solidified metal is continuously withdrawn, and cooling means for extracting heat from the metal in said passage via the mold wall, the mold wall defining said passage being of graphite and having a compound configuration adapted to maintain a uniform wiping contact with the metal as it moves through said passage.

14. Apparatus for continuously casting metals comprising the combination with a mold mounted to receive molten metal directly from a vessel constituting a supply thereof, and a water jacket surrounding the mold for solidifying metal continuously passing through the latter, of means for adjusting said jacket longitudinally with respect to the axis of the cavity of said mold.

15. Apparatus for continuously casting metals comprising, in combination, a mold with a cavity

extending completely therethrough adapted to continuously receive molten metal from a source thereof into one end of said mold and to continuously discharge solidified metal from the other end, said mold having its discharge end externally tapered, a cooling jacket surrounding said tapered end, the bore of said jacket being correspondingly, but inversely, tapered, and means for adjustably positioning said jacket on said mold longitudinally to the axis of the mold cavity.

16. Apparatus for continuously casting metals comprising a container for molten metal, a mold having its inlet opening in said container for receiving molten metal therefrom, and cooling instrumentalities for solidifying metal in said mold to permit the casting to be continuously withdrawn therefrom, said mold presenting a continuous graphite surface in continuous engagement with the metal in its passage therethrough, the mold cavity being of lesser cross-sectional area at the discharge end of the mold than at the region where the metal is solidified but not less than the cross-sectional area of the casting.

17. Apparatus for continuously casting metal comprising a graphite mold mounted in communication with a supply of molten metal and cooling means for solidifying molten metal as it is continuously passed through said mold, the discharge opening of said mold being of lesser cross-sectional area than that of the region in which solidification of the metal is effected but greater than the cross-sectional area of the casting withdrawn from the mold.

18. Apparatus for continuously casting metal comprising a vessel constituting a source of metal to be cast, a mold into which molten metal is introduced from the source and from which solidified metal is continuously withdrawn as a casting of indeterminate length, and cooling means for the mold, said mold having an internal compound taper which presents, during the casting operation, a substantially straight-line resultant from the mold intake to the region of metal solidification and a converging taper from that region to the mold outlet sufficient to compensate for the contraction of the casting being withdrawn without binding.

19. Apparatus for the continuous casting of metals comprising a mold body defining a chamber into which molten metal is continuously introduced from a source thereof and from which solidified metal is continuously withdrawn as a casting of indeterminate length, and cooling means around the mold body adapted to chill the molten metal to solidify same, the said mold having an internal compound taper of predetermined amounts such that the said compound taper exhibits a substantially straight-line resultant during casting operations arising from expansion and contraction stresser imparted to the mold incident to the heating thereof by the metal and the cooling thereof by the cooling means, said straight-line resultant extending from the intake of the mold to the solidifying zone of the metal, the taper thereafter being uniform and sufficient to conform to the contraction of the casting as the latter is withdrawn from the mold while being insufficient to cause the mold to bind upon the newly-formed casting as it moves through the mold.

20. Apparatus for continuously casting metals comprising a mold into which molten metal is continuously introduced from a source thereof and from which solidified metal is continuously with-

drawn as a casting of indeterminate length, the said mold being provided with a compound internal taper which diverges gradually from the intake of the mold to a point slightly in advance of the zone in the mold in which solidification of the metal occurs under commercial casting speeds, whence the divergence becomes more pronounced until the zone of solidification is reached in which zone there is substantially no taper but at the end of which the taper gradually converges in the direction of travel of the newly solidified metal, the diverging tapers being predetermined so as to present substantially a straight-line resultant during casting operations and the converging taper being predetermined to conform substantially exactly to the contraction of the metal being withdrawn at predetermined commercial casting rates.

21. Apparatus for the continuous casting of metals comprising a mold into which molten metal is continuously introduced from a source thereof and from which solidified metal is continuously withdrawn as a casting of indeterminate length, and cooling means for the mold, the said mold having an internal compound taper such that under casting operations a portion of the said compound taper defines substantially a straight wall for a distance from the metal intake of the mold to within the solidifying zone of the metal, and presents thereafter a uniformly converging taper in the direction of withdrawal of the metal sufficient to engage the newly-solidified metal but without binding as the metal is continuously withdrawn from the mold at predetermined casting rates.

22. Apparatus for the continuous casting of metals comprising a mold into which molten metal is continuously introduced from a supply thereof and from which solidified metal is continuously withdrawn as a casting of indeterminate length, the said mold having an internal tapered configuration predetermined to conform substantially exactly to changes in diameter of the metal being cast incident to the amount of cooling imparted thereto in the mold in predetermined zones during withdrawal of the metal through the die at commercial casting speeds.

23. Apparatus for continuously casting metals comprising a mold vertically mounted to continuously receive molten metal from a source thereof, a cooling jacket for said mold adapted to extract heat through the mold walls and thereby solidify metal continuously passing through said mold, and a mold extension in alignment with said mold for engaging the casting continuously issuing therefrom, said mold extension comprising a plurality of separate cooling units, each of said separate units in turn comprising a plurality of yieldably interconnected segments.

24. Apparatus for continuously casting metal comprising a mold mounted in a vessel adapted to continuously supply molten metal to said mold, the cavity of said mold constituting a molten metal inlet at one end and a casting outlet at the other end, a cooling jacket for the mold for solidifying metal continuously passing there-through, complementary tapers on the outside of said mold and inside of said jacket insuring a close fit therebetween, and auxiliary cooling means supported independently of the aforesaid mold and jacket but in alignment therewith, said means comprising a plurality of separate cooling units, each unit comprising a plurality of separate segments yieldably interconnected for continuous self-adjustment with respect to the cast-

ing which issues continuously from the mold and passes through said units.

25. Apparatus for continuously casting metals comprising a vessel for the metal to be cast, a mold mounted in said vessel continuously receiving molten metal from the vessel and continuously discharging a solidified casting of indeterminate length, a mold extension for receiving the casting from said mold, said mold extension comprising a plurality of units, each of said units comprising a plurality of yieldably connected segments, cooling means for said mold and mold extension adapted to impart different cooling rates to different zones thereof, and means for maintaining the mold extension in operative alignment with the mold.

26. Apparatus for continuously casting metal comprising a furnace interiorly divided into first and second compartments, a mold mounted in said second compartment, a plurality of superposed floors in said first compartment, and ports between floors spaced to reverse the flow of metal from one floor to the next, all molten metal-contacting surfaces of said apparatus comprising carbon.

27. Apparatus for continuously casting metal comprising a furnace having a multiple-floored hearth of graphite, ports in all upper floors for the passage of molten metal from one floor to the next lower floor, a mold mounted adjacent said hearth, and electrical resistor elements above said hearth for heating said furnace.

28. Apparatus for continuously casting metal comprising a furnace interiorly divided into metal-receiving and metal-casting compartments, all metal-contacting surfaces of both compartments being of carbon, a mold mounted in said metal-casting compartment, and a gas venting means positioned directly above the intake of said mold.

29. Apparatus for continuously casting metals comprising a first compartment having a plural-

ity of superposed floors with ports in said floors enabling flow of molten metal from one to the other, a second compartment having a mold mounted therein, and a gas venting means above said mold, the cross-sectional area of the vent in said means being substantially less than the cross-sectional area of said mold.

30. Apparatus for continuously casting metal comprising a reservoir for molten metal, all metal-contacting surfaces of which are of graphite, a mold holder externally threaded for mounting in the bottom of said reservoir and internally threaded to receive a mold, a mold externally threaded to mesh with said holder, the top of said mold projecting a short distance above the level of the holder and the bottom of the reservoir, and a gas venting means mounted over the intake of said mold.

31. Apparatus for continuously casting metal comprising a furnace with a graphite-lined, multiple-floored hearth defining a reservoir for molten metal, carbon resistors above said hearth for controlling the temperature of the molten metal, a mold in communication with said reservoir for receiving molten metal therefrom and continuously solidifying same into a casting of indefinite length, and a gas venting means mounted above said mold for receiving and discharging gas expelled by the metal as it solidifies.

32. Apparatus for continuously casting metal comprising a furnace interiorly divided into metal-receiving and metal-casting compartments, a mold mounted in said metal-casting compartment, and a gas venting means positioned above the intake of said mold and arranged to vent liberated gases while preventing contact of said gases with the molten metal being cast.

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